Federal Aviation Administration – Regulations and Policies
Aviation Rulemaking Advisory Committee

Transport Airplane and Engine Issue Area
Loads and Dynamics Harmonization Working Group

Task 11 – Taxi, Takeoff and Landing Roll

Task Assignment

Aviation Rulemaking Advisory Committee; Loads and Dynamics Harmonization Working Group

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of establishment of Loads and Dynamics Harmonization Working Group.

SUMMARY: Notice is given of the establishment of the Loads and Dynamics Harmonization Working Group of the Aviation Rulemaking Advisory Committee (ARAC). This notice informs the public of the activities of the ARAC on transport airplane and engine issues.

FOR FURTHER INFORMATION CONTACT: Mr. William J. (Joe) Sullivan, Assistant Executive Director, Aviation Rulemaking Advisory Committee, Aircraft Certification Service (AIR-3), 800 Independence Avenue, SW., Washington, DC 20591, Telephone: (202) 267-9554; FAX: (202) 267-5364.

SUPPLEMENTARY INFORMATION: The Federal Aviation Administration (FAA) has established an Aviation Rulemaking Advisory Committee (ARAC) (56 FR 2190, January 22, 1991; and 58 FR 9230, February 19, 1993). One area the ARAC deals with is transport airplane and engine issues (56 FR 31995; July 12, 1991). These issues involve the airworthiness standards for transport airplanes, engines and propellers in parts 25, 33 and 35 of the Federal Aviation Regulations (14 CFR parts 25, 33 and 35) which are the responsibility of the FAA Director of Aircraft Certification.

The FAA announced at the Joint Aviation Authorities (JAA)-Federal Aviation Administration (FAA) Harmonization Conference in Toronto, Ontario, Canada, (June 2–5, 1992) that it would consolidate within the Aviation Rulemaking Advisory Committee structure an ongoing objective to "harmonize" the Joint Aviation Requirements (JAR) and the Federal Aviation Regulations (FAR). Coincident with that announcement, the FAA assigned to the ARAC those projects related to JAR/FAR 25, 33 and 35 harmonization which were then in the process of being coordinated between the JAA and the FAA. The harmonization process included the intention to present the results of JAA/FAA coordination to the public in the form of either a Notice of Proposed Rulemaking or an advisory circular—an objective comparable to and compatible with that assigned to the Aviation Rulemaking Advisory Committee. The Loads and Dynamics Harmonization Working Group is being formed to address loads and dynamics issues in JAR/FAR parts 25 identified below. The Loads and Dynamics Harmonization Working Group will forward recommendations to the ARAC which will determine whether to forward them to the FAA.

Specifically, the Working Group's tasks are the following: The Loads and Dynamics Harmonization Working Group is charged with making recommendations to the ARAC concerning the FAA disposition of the following subjects recently coordinated between the JAA and the FAA:

Task 1—General Design Loads

Develop new or revised requirements, and associated advisory and guidance material, for the general design loads for transport category airplanes (FAR 25.331, 25.335, 25.341, 25.345, 25.351, 25.371, 25.427, 25.483, 25.511, 25.561 and 25.963 and other conforming changes).

Task 2—Engine Torque and Gyroscopic Loads

Develop new or revised requirements, and associated advisory and guidance material, for determining the design loads for engine seizure conditions (FAR 25.361, 25.371 and other conforming changes).

Task 3—Flutter, Deformation and Fail-Safe Criteria:

Develop new or revised advisory and guidance material for flutter, deformation and fail-safe criteria (FAR 25.629).

Reports

A. Recommend time line(s) for completion of each task, including rationale, for consideration at the meeting of the ARAC to consider transport airplane and engine issues held following publication of this notice.

B. Give a detailed conceptual presentation on each task to the ARAC before proceeding with the work stated under items C and D, below. If tasks 1 and 2 require the development of more than one Notice of Proposed Rulemaking, identify what proposed amendments will be included in each notice.

C. Draft one or more Notices of Proposed Rulemaking for Tasks 1 and 2 proposing new or revised requirements, a supporting economic analysis and other required analysis, advisory and guidance material, and any other collateral documents the Working Group determines to be needed.

D. Draft appropriate advisory and guidance material for Task 3.

E. Give a status report on each task at each meeting of the ARAC held to consider transport airplane and engine issues.

The Loads and Dynamics Harmonization Working Group will be comprised of experts from those organizations having an interest in the tasks assigned. A Working Group member need not necessarily be a representative of one of the member organizations of the ARAC. An individual who has expertise in the subject matter and wishes to become a member of the Working Group should *write* the person listed under the caption "FOR FURTHER INFORMATION CONTACT" expressing that desire, describing his or her interest in the task, and the expertise he or she would bring to the Working Group. The request will be reviewed with the Chairs of the ARAC Transport Airplane and Engine Interest Issues and the Loads and Dynamics Working Group, and the individual will be advised whether or not the request can be accommodated.

The Secretary of Transportation has determined that the information and use of the ARAC is necessary in the public interest in connection with the performance of duties of the FAA by law. Meetings of the ARAC will be open to the public except as authorized by section 10(d) of the Federal Advisory Committee Act. Meetings of the Loads and Dynamics Harmonization Working Group will not be open to the public except to the extent that individuals with an interest and expertise are selected to participate. No public announcement of Working Group meetings will be made.

Issued in Washington, DC, on March 8, 1993.

William J. Sullivan,

Assistant Executive Director for Transport Airplane and Engine Issues, Aviation Rulemaking Advisory Committee.

[FR Doc. 93-5815 Filed 3-12-93; 8:45 am]

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Recommendation Letter

400 Main Street
East Hartford, Connecticut 06108

Pratt & Whitney
A United Technologies Company

November 12, 1998

Department of Transportation
Federal Aviation Administration
800 Independence Avenue
Washington, DC 20591

Attn: Mr. Tom McSweeny, Associate Administrator for Regulation and Certification

Subject: ARAC Advisory Circular Recommendation

Dear Guy:

The ARAC Transport Airplane and Engine Issues Group (TAEIG) is pleased to forward the attached advisory material to the FAA for further action. This package has been approved by the TAEIG and contains proposed Advisory Circular, AC 25.491-1, Taxi, Takeoff and Landing Roll Design Loads.

Please feel free to contact us if we can be of assistance in any way.

Sincerely,

Craig R. Bolt

Craig R. Bolt
Assistant Chair, ARAC TAEIG
boltcr@pweh.com
(Ph: 860-565-9348/Fax: 860-565-5794)

CRB/amr

Attachment (to addressee only)

cc: Bob Benjamin
Vic Card
Jean Casciano
Brenda Courtney
Chuck Huber
Herb Lancaster

Acknowledgement Letter

HRM-25

U.S. Department
of Transportation
**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, DC 20591

MAR 12 1999

Mr. Craig R. Bolt
Assistant Chair, ARAC TAEIG
Pratt & Whitney
400 Main Street
East Hartford, Connecticut 06106

Dear Mr. Bolt:

Thank you for your November 12, 1998, letter transmitting a recommendation addressing Advisory Circular No. 25.491-1, Taxi, Takeoff, and Landing Roll Design Loads.

The recommendation package has been forwarded to the Federal Aviation Administration (FAA) Transport Airplane Directorate for review and evaluation. We will process the package as quickly as possible and notify you of the agency decision.

Let me thank the ARAC and, in particular, the members of the Load and Dynamics Harmonization Working Group for their efforts in completing the task assigned by the FAA.

Sincerely,

Margaret Gilligan

for Thomas E. McSweeny
Associate Administrator for Regulation
and Certification

Recommendation

U.S. Department
of Transportation

**Federal Aviation
Administration**

Advisory Circular

TAXI, TAKEOFF AND LANDING ROLL DESIGN LOADS	**Date:** **Initiated by: ANM-110**	**AC No. 25.491-1** **Change:**

1. PURPOSE. This advisory circular (AC) sets forth acceptable methods of compliance with the provisions of part 25 of the Federal Aviation Regulations (FAR) dealing with the certification requirements for taxi, takeoff and landing roll design loads. Guidance information is provided for showing compliance with § 25.491 of the FAR, relating to structural design for airplane operation on paved runways and taxiways normally used in commercial operations. Other methods of compliance with the requirements may be acceptable.

2. RELATED FAR SECTIONS. The contents of this AC are considered by the Federal Aviation Administration (FAA) in determining compliance with § 25.491 of the FAR. Related sections are §§ 25.305(c) and 25.235.

3. BACKGROUND.

a. All paved runways and taxiways have an inherent degree of surface unevenness, or roughness. This is the result of the normal tolerances of engineering standards required for construction, as well as the result of events such as uneven settlement and frost heave. In addition, repair of surfaces on an active runway or taxiway can result in temporary ramped surfaces. Many countries have developed criteria for runway surface roughness. The International Civil Aviation Organization (ICAO) standards are published in ICAO Annex 14.

b. In the late 1940's, as airplanes became larger, more flexible, and operated at higher ground speeds, consideration of dynamic loads during taxi, landing rollout, and takeoff became important in airplane design. The Civil Aeronautics Administration, in Civil Air Regulations 4b (CAR 4b), § 4b.172, required the effects of landing gear deflection during taxiing over the roughest ground expected in service to be considered relative to its effect on damage to structural components. The CAR 4b, § 4b.235, also required the airplane be designed, in part, to withstand loads calculated under § 4b.172. Those regulations were carried over to part 25 of the FAR as § 25.235 and § 25.491 respectively. Substantiation of the effect of ground loads on flexible structure is required by § 25.305(c).

c. Several approaches had been taken by different manufacturers in complying with the noted regulations. If dynamic effects due to rigid body modes or airframe flexibility during taxi were not considered critical, some manufacturers used a simplified static analysis where a static inertia force was applied to the airplane using a load factor of 2.0 for single axle gears or 1.7 for multiple axle gears. The lower 1.7 factor was justified based on an assumption that there was a load alleviating effect resulting from rotation of the beam, on which the forward and aft axles are attached, about the central pivot point on the strut. The static load factor approach was believed to encompass any dynamic effects and it had the benefit of a relatively simple analysis.

d. As computers became more powerful and dynamic analysis methods became more sophisticated, it was found that dynamic effects sometimes resulted in loads greater than those which were predicted by the static criterion. Some manufacturers performed calculations using a series of harmonic bumps to represent a runway surface, tuning the bumps to excite various portions of the structure at a given speed. U.S. Military Standard 8862 defines amplitude and wavelengths of 1-cosine bumps intended to excite low speed plunge, pitch and wing first bending modes.

e. Some manufacturers used actual runway profile data to calculate loads. The runway profiles of the San Francisco Runway 28R or Anchorage Runway 24, which were known to cause high loads on airplanes and were the subject of pilot complaints until resurfaced, have been used in a series of bi-directional constant speed analytical runs to determine loads. In some cases, accelerated runs have been used, starting from several points along the runway. The profiles of those runways are described in NASA Reports CR-119 and TN D-5703. Such deterministic dynamic analyses have in general proved to be satisfactory.

f. Some manufacturers have used a statistical power spectral density (PSD) approach, especially to calculate fatigue loads. Extensive PSD runway roughness data exist for numerous world runways. The PSD approach is not considered practical for calculation of limit loads due to difficulties in simulating the non-linearities in the landing gear shock absorption features.

g. Because the various methods described above produce different results, the guidance information given in paragraphs 4, 5, and 6 of this AC should be used when demonstrating compliance with § 25.491.

4. RUNWAY PROFILE CONDITION.

a. Consideration of airframe flexibility and landing gear dynamic characteristics is necessary in most cases. A deterministic dynamic analysis, based on the San Francisco Runway 28R (before it was resurfaced), described in Table 1 of this AC, is an acceptable method for compliance.

b. Airplane design loads should be developed for the most critical conditions arising from taxi, takeoff, and landing run. The airplane analysis model should include significant airplane rigid body and flexible modes, and the appropriate landing gear and tire characteristics. Unless the airplane has design features that would result in significant asymmetric loads, only the symmetric cases need be investigated.

c. Airplane steady aerodynamic effects should normally be included. However, they may be ignored if their deletion is shown to produce conservative loads. Unsteady aerodynamic effects on dynamic response may be neglected.

d. Conditions should be run at the maximum takeoff weight and the maximum landing weight with critical combinations of wing fuel, payload, and extremes of center of gravity (c.g.) range. For airplanes with trimable stabilizers, the stabilizer should be set within the appropriate green band setting for takeoff cases and at the recommended final approach setting for landing cases. The elevator should be assumed faired throughout the takeoff or landing run, unless other normal procedures are specified in the flight manual.

e. A series of constant speed runs should be made in both directions from 20 knots up to the maximum ground speeds expected in normal operation (V_R for takeoff conditions, 1.25 V_{L2} for landing conditions). Using only accelerated runs is not recommended due to the possibility that the speed/roughness points which could produce peak dynamic loads could be missed. For maximum take-off weight cases, the analysis should account for normal takeoff flap and control settings and consider both zero and maximum thrust. For maximum landing weight cases, the analysis should account for normal flap and spoiler positions following landing, and steady pitching moments equivalent to those produced by braking with a coefficient of friction of 0.3 with and without reverse thrust. The effects of automatic braking systems that reduce braking in the presence of reverse thrust may be taken into account.

5. DISCRETE LOAD CONDITION. One of the following discrete limit load conditions should be evaluated:

a. With all landing gears in contact with the ground, the condition of a vertical load equal to 1.7 times the static ground reaction should be investigated under the most adverse airplane loading distribution at maximum takeoff weight, with and without thrust from the engines;

b. As an alternative to paragraph 5(a) above, it would be acceptable to undertake dynamic analyses under the same conditions considered in paragraph 4 of this AC considering the aircraft response to each of the following pairs of identical and contiguous 1-cosine upwards bumps on an otherwise smooth runway:

(i) Bump wavelengths equal to the mean longitudinal distance between nose and main landing gears, or between the main and tail landing gears, as appropriate; and separately.

(ii) Bump wavelengths equal to twice this distance.

The bump height in each case should be defined as:

$$H = 1.2 + 0.023\sqrt{L}$$

Where--

H = the bump height (inches).

L = the bump wavelength (inches)

6. COMBINED LOAD CONDITION. A condition of combined vertical, side and drag loads should be investigated for the main landing gear. In the absence of a more rational analysis a vertical load equal to 90% of the ground reaction from paragraph 5 above should be combined with a drag and side load of 20% of the vertical load.

7. TIRE CONDITIONS. The calculation of maximum gear loads in accordance with paragraphs 4, 5, and 6, may be performed using fully inflated tires. For multiple wheel units, the maximum gear loads should be distributed between the wheels in accordance with the criteria of § 25.511.

TABLE 1

SAN FRANCISCO RUNWAY 28R
ONE TRACK
LENGTH: 3880 FEET
NUMBER OF POINTS: 1941
POINT SPACING: 2 FEET
ELEVATIONS: FEET
REFERENCE SOURCE: REPORT TO NASA (EFFECTS OF RUNWAY UNEVENNESS ON THE DYNAMIC RESPONSE OF SUPERSONIC TRANSPORTS), JULY 1964, U. OF CALIF. BERKLEY.

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RUNWAY ELEVATION POINTS IN FEET (READ ROW WISE):

10.300	10.310	10.300	10.300	10.310	10.320	10.330	10.340
10.350	10.360	10.360	10.370	10.370	10.370	10.380	10.390
10.400	10.400	10.410	10.410	10.420	10.430	10.430	10.440
10.440	10.440	10.440	10.440	10.450	10.460	10.470	10.470
10.480	10.490	10.490	10.500	10.500	10.500	10.500	10.500
10.500	10.490	10.490	10.490	10.490	10.500	10.500	10.510
10.510	10.520	10.520	10.520	10.530	10.530	10.540	10.540
10.550	10.550	10.550	10.550	10.540	10.550	10.550	10.560
10.570	10.570	10.570	10.570	10.570	10.580	10.570	10.570
10.580	10.570	10.560	10.560	10.560	10.560	10.560	10.560
10.560	10.560	10.550	10.550	10.550	10.560	10.570	10.570
10.570	10.570	10.560	10.550	10.550	10.550	10.550	10.550
10.560	10.560	10.560	10.560	10.550	10.540	10.530	10.520
10.520	10.520	10.520	10.520	10.520	10.530	10.520	10.520
10.510	10.520	10.520	10.510	10.520	10.520	10.530	10.530
10.530	10.530	10.530	10.530	10.530	10.530	10.530	10.520
10.530	10.540	10.540	10.540	10.540	10.540	10.540	10.550
10.550	10.540	10.550	10.550	10.560	10.570	10.580	10.590
10.600	10.610	10.620	10.630	10.650	10.660	10.660	10.670
10.660	10.670	10.670	10.670	10.670	10.670	10.660	10.660
10.650	10.650	10.650	10.650	10.660	10.670	10.670	10.670
10.680	10.680	10.680	10.690	10.690	10.690	10.700	10.710
10.710	10.720	10.720	10.710	10.720	10.720	10.720	10.710
10.720	10.720	10.730	10.730	10.740	10.750	10.750	10.780
10.770	10.780	10.790	10.800	10.810	10.810	10.820	10.830
10.840	10.850	10.860	10.860	10.860	10.860	10.850	10.860
10.860	10.870	10.870	10.870	10.870	10.870	10.860	10.850
10.840	10.840	10.830	10.830	10.840	10.850	10.860	10.870
10.870	10.880	10.890	10.900	10.920	10.930	10.940	10.950

10.950	10.950	10.950	10.950	10.950	10.960	10.970	10.980
10.980	10.990	10.990	10.990	11.000	11.010	11.010	11.010
11.010	10.980	10.960	10.950	10.950	10.950	10.960	10.970
10.970	10.980	10.970	10.970	10.980	10.990	11.000	11.010
11.030	11.030	11.030	11.030	11.030	11.030	11.030	11.030
11.020	11.020	11.030	11.040	11.050	11.050	11.040	11.060
11.070	11.070	11.080	11.080	11.090	11.100	11.120	11.130
11.140	11.140	11.150	11.160	11.170	11.170	11.170	11.170
11.170	11.180	11.180	11.180	11.170	11.170	11.170	11.170
11.190	11.170	11.180	11.180	11.180	11.190	11.190	11.190
11.200	11.210	11.210	11.210	11.200	11.200	11.200	11.190
11.180	11.180	11.170	11.160	11.150	11.140	11.140	11.140
11.120	11.110	11.090	11.090	11.090	11.090	11.090	11.090
11.090	11.090	11.090	11.090	11.090	11.090	11.090	11.080
11.080	11.080	11.080	11.070	11.060	11.050	11.040	11.030
11.020	11.010	11.000	10.990	10.990	10.980	10.990	10.980
10.980	10.980	10.980	10.980	10.980	10.990	10.990	11.000
11.000	11.000	11.000	11.000	11.010	11.020	11.020	11.020
11.020	11.020	11.020	11.010	11.010	11.000	11.000	11.000
11.000	11.000	11.000	10.990	10.990	10.980	10.990	10.990
11.000	11.010	11.010	11.010	11.030	11.040	11.030	11.050
11.060	11.070	11.060	11.070	11.080	11.080	11.080	11.090
11.090	11.080	11.080	11.080	11.080	11.080	11.080	11.070
11.080	11.080	11.080	11.080	11.090	11.080	11.080	11.070
11.070	11.060	11.050	11.050	11.040	11.050	11.040	11.040
11.040	11.040	11.040	11.040	11.040	11.030	11.030	11.030
11.030	11.020	11.020	11.020	11.020	11.020	11.020	11.030
11.030	11.040	11.050	11.050	11.060	11.060	11.060	11.070
11.070	11.070	11.070	11.070	11.080	11.080	11.070	11.070
11.070	11.060	11.060	11.060	11.060	11.060	11.070	11.070
11.080	11.080	11.090	11.090	11.090	11.090	11.100	11.090
11.090	11.090	11.090	11.080	11.080	11.070	11.070	11.060
11.070	11.090	11.100	11.100	11.110	11.110	11.120	11.120
11.120	11.110	11.110	11.110	11.110	11.110	11.100	11.110
11.110	11.120	11.120	11.120	11.110	11.110	11.120	11.110
11.110	11.110	11.100	11.100	11.120	11.130	11.150	11.160
11.170	11.180	11.180	11.190	11.190	11.200	11.220	11.220
11.230	11.230	11.230	11.240	11.250	11.250	11.260	11.240

11.270	11.280	11.280	11.300	11.310	11.320	11.330	11.340
11.340	11.340	11.340	11.330	11.320	11.320	11.310	11.320
11.320	11.310	11.310	11.310	11.320	11.310	11.320	11.330
11.340	11.350	11.350	11.360	11.360	11.360	11.370	11.370
11.370	11.370	11.380	11.380	11.380	11.380	11.380	11.380
11.380	11.380	11.380	11.370	11.370	11.370	11.370	11.380
11.380	11.390	11.380	11.380	11.390	11.400	11.410	11.410
11.420	11.430	11.440	11.440	11.450	11.460	11.460	11.460
11.460	11.470	11.480	11.480	11.480	11.490	11.500	11.500
11.500	11.500	11.500	11.500	11.490	11.490	11.490	11.480
11.470	11.460	11.460	11.480	11.460	11.470	11.470	11.470
11.470	11.460	11.450	11.450	11.450	11.460	11.460	11.460
11.450	11.450	11.450	11.450	11.450	11.460	11.460	11.460
11.480	11.470	11.470	11.480	11.480	11.480	11.480	11.490
11.490	11.500	11.510	11.520	11.520	11.520	11.520	11.520
11.520	11.520	11.530	11.520	11.520	11.520	11.530	11.530
11.530	11.530	11.530	11.530	11.540	11.530	11.520	11.520
11.510	11.530	11.520	11.540	11.530	11.540	11.530	11.540
11.530	11.540	11.550	11.540	11.540	11.540	11.540	11.530
11.520	11.510	11.500	11.490	11.490	11.490	11.490	11.490
11.480	11.470	11.470	11.470	11.460	11.470	11.470	11.480
11.470	11.460	11.460	11.460	11.460	11.460	11.470	11.470
11.470	11.460	11.460	11.440	11.430	11.410	11.400	11.390
11.380	11.370	11.360	11.360	11.350	11.350	11.350	11.350
11.350	11.340	11.340	11.330	11.320	11.320	11.320	11.310
11.310	11.300	11.290	11.290	11.280	11.280	11.280	11.280
11.280	11.270	11.270	11.270	11.260	11.260	11.250	11.250
11.240	11.230	11.220	11.210	11.190	11.180	11.170	11.170
11.150	11.130	11.120	11.100	11.100	11.180	11.170	11.140
11.140	11.120	11.000	10.970	10.950	10.940	10.920	10.910
10.920	10.920	10.910	10.930	10.930	10.930	10.930	10.930
10.930	10.930	10.930	10.930	10.930	10.930	10.940	10.940
10.940	10.940	10.950	10.940	10.930	10.940	10.940	10.930
10.920	10.920	10.920	10.910	10.910	10.910	10.910	10.900
10.890	10.880	10.870	10.890	10.880	10.880	10.880	10.870
10.860	10.850	10.860	10.860	10.850	10.850	10.850	10.840
10.840	10.840	10.830	10.830	10.820	10.820	10.810	10.810
10.800	10.790	10.790	10.790	10.790	10.790	10.790	10.800

10.800	10.810	10.820	10.820	10.830	10.840	10.850	10.850
10.850	10.870	10.870	10.880	10.870	10.880	10.870	10.870
10.870	10.870	10.860	10.850	10.840	10.840	10.840	10.840
10.840	10.830	10.820	10.820	10.820	10.820	10.820	10.820
10.830	10.820	10.830	10.820	10.820	10.820	10.820	10.810
10.810	10.810	10.810	10.820	10.820	10.820	10.830	10.830
10.830	10.840	10.840	10.850	10.860	10.860	10.860	10.880
10.870	10.860	10.860	10.860	10.870	10.870	10.860	10.850
10.850	10.890	10.910	10.910	10.920	10.920	10.930	10.930
10.930	10.940	10.940	10.950	10.940	10.930	10.930	10.920
10.930	10.910	10.910	10.900	10.900	10.900	10.910	10.910
10.890	10.900	10.910	10.910	10.910	10.920	10.930	10.940
10.940	10.940	10.940	10.940	10.950	10.930	10.930	10.930
10.930	10.920	10.930	10.930	10.930	10.930	10.910	10.900
10.910	10.910	10.910	10.910	10.910	10.910	10.910	10.900
10.900	10.890	10.900	10.900	10.900	10.910	10.900	10.910
10.890	10.890	10.890	10.890	10.890	10.880	10.880	10.870
10.870	10.870	10.860	10.880	10.870	10.860	10.870	10.870
10.860	10.850	10.850	10.850	10.860	10.850	10.860	10.860
10.860	10.870	10.870	10.870	10.870	10.870	10.880	10.870
10.880	10.870	10.880	10.880	10.880	10.880	10.880	10.890
10.900	10.890	10.890	10.890	10.890	10.900	10.890	10.890
10.880	10.870	10.880	10.870	10.870	10.870	10.870	10.880
10.880	10.880	10.880	10.880	10.880	10.890	10.890	10.890
10.890	10.890	10.890	10.890	10.880	10.880	10.890	10.880
10.890	10.880	10.880	10.880	10.880	10.880	10.870	10.870
10.870	10.870	10.870	10.880	10.880	10.880	10.890	10.890
10.900	10.910	10.920	10.920	10.930	10.920	10.920	10.920
10.920	10.920	10.920	10.920	10.930	10.930	10.930	10.930
10.930	10.940	10.930	10.930	10.930	10.930	10.930	10.920
10.920	10.910	10.900	10.920	10.910	10.910	10.900	10.900
10.900	10.880	10.880	10.860	10.850	10.850	10.840	10.840
10.840	10.840	10.850	10.850	10.850	10.850	10.850	10.850
10.860	10.860	10.860	10.870	10.880	10.880	10.890	10.900
10.910	10.910	10.920	10.920	10.930	10.940	10.940	10.950
10.960	10.960	10.970	10.990	10.990	10.990	10.990	11.000
11.000	11.000	11.010	11.010	11.020	11.020	11.020	11.040
11.050	11.050	11.060	11.060	11.050	11.040	11.030	11.030

11.020	11.030	11.030	11.040	11.050	11.060	11.070	11.090
11.100	11.100	11.110	11.120	11.140	11.140	11.150	11.160
11.160	11.160	11.150	11.150	11.160	11.150	11.140	11.140
11.140	11.140	11.140	11.140	11.150	11.150	11.150	11.150
11.150	11.150	11.160	11.160	11.150	11.150	11.160	11.160
11.160	11.160	11.160	11.160	11.160	11.160	11.170	11.170
11.170	11.170	11.170	11.170	11.170	11.160	11.150	11.150
11.140	11.140	11.140	11.130	11.120	11.120	11.120	11.120
11.120	11.120	11.130	11.130	11.140	11.150	11.160	11.170
11.180	11.190	11.200	11.200	11.220	11.230	11.240	11.240
11.250	11.260	11.270	11.280	11.280	11.290	11.300	11.300
11.300	11.310	11.300	11.310	11.310	11.310	11.310	11.300
11.300	11.300	11.290	11.290	11.290	11.290	11.290	11.290
11.290	11.290	11.290	11.300	11.300	11.310	11.310	11.320
11.320	11.330	11.330	11.340	11.350	11.350	11.350	11.350
11.350	11.350	11.360	11.360	11.350	11.350	11.350	11.350
11.350	11.350	11.340	11.340	11.340	11.340	11.350	11.350
11.350	11.340	11.330	11.330	11.330	11.330	11.330	11.330
11.330	11.320	11.330	11.330	11.330	11.330	11.330	11.340
11.340	11.340	11.350	11.350	11.350	11.350	11.350	11.350
11.350	11.350	11.360	11.360	11.360	11.350	11.350	11.350
11.350	11.350	11.350	11.360	11.360	11.360	11.360	11.360
11.370	11.380	11.380	11.390	11.390	11.400	11.410	11.420
11.420	11.430	11.430	11.420	11.420	11.430	11.430	11.430
11.430	11.430	11.430	11.440	11.440	11.450	11.460	11.460
11.470	11.480	11.480	11.490	11.490	11.500	11.500	11.510
11.520	11.520	11.520	11.520	11.520	11.520	11.520	11.520
11.520	11.520	11.510	11.510	11.510	11.500	11.500	11.500
11.500	11.510	11.510	11.510	11.520	11.520	11.520	11.520
11.530	11.530	11.530	11.520	11.520	11.520	11.520	11.520
11.520	11.530	11.530	11.530	11.540	11.530	11.530	11.540
11.540	11.540	11.540	11.530	11.530	11.530	11.530	11.540
11.540	11.540	11.550	11.550	11.550	11.560	11.550	11.550
11.550	11.550	11.540	11.530	11.530	11.530	11.510	11.520
11.520	11.530	11.530	11.540	11.550	11.560	11.560	11.570
11.570	11.570	11.580	11.580	11.580	11.580	11.580	11.580
11.590	11.590	11.590	11.590	11.580	11.570	11.570	11.580
11.570	11.570	11.570	11.580	11.580	11.590	11.600	11.620

11.610	11.610	11.610	11.610	11.610	11.620	11.630	11.640
11.650	11.660	11.670	11.670	11.670	11.680	11.700	11.720
11.730	11.740	11.760	11.770	11.780	11.800	11.820	11.820
11.820	11.830	11.820	11.820	11.830	11.840	11.830	11.830
11.830	11.830	11.830	11.830	11.840	11.850	11.860	11.870
11.880	11.880	11.890	11.900	11.900	11.900	11.900	11.900
11.900	11.910	11.910	11.900	11.910	11.910	11.910	11.910
11.900	11.910	11.910	11.920	11.920	11.920	11.920	11.920
11.920	11.920	11.910	11.910	11.920	11.910	11.910	11.910
11.910	11.900	11.900	11.900	11.900	11.900	11.900	11.900
11.900	11.900	11.900	11.910	11.920	11.920	11.920	11.930
11.930	11.930	11.930	11.940	11.940	11.950	11.950	11.950
11.960	11.960	11.960	11.960	11.960	11.960	11.950	11.940
11.930	11.920	11.920	11.920	11.920	11.920	11.920	11.920
11.920	11.920	11.920	11.920	11.910	11.900	11.900	11.900
11.900	11.900	11.900	11.900	11.900	11.900	11.900	11.900
11.900	11.900	11.900	11.900	11.900	11.890	11.880	11.880
11.870	11.870	11.860	11.860	11.850	11.850	11.840	11.840
11.840	11.840	11.840	11.850	11.870	11.890	11.890	11.900
11.890	11.920	11.950	11.950	11.950	11.940	11.940	11.930
11.920	11.920	11.910	11.900	11.900	11.890	11.880	11.870
11.860	11.850	11.840	11.840	11.840	11.830	11.820	11.820
11.810	11.830	11.830	11.830	11.840	11.840	11.840	11.840
11.820	11.830	11.820	11.830	11.830	11.840	11.840	11.840
11.850	11.840	11.840	11.840	11.850	11.850	11.850	11.860
11.860	11.840	11.840	11.840	11.840	11.840	11.840	11.840
11.840	11.840	11.840	11.840	11.840	11.830	11.830	11.830
11.820	11.830	11.830	11.830	11.820	11.820	11.830	11.820
11.830	11.830	11.840	11.840	11.830	11.830	11.830	11.830
11.830	11.840	11.840	11.840	11.850	11.850	11.850	11.850
11.840	11.840	11.850	11.850	11.860	11.860	11.870	11.870
11.870	11.870	11.870	11.860	11.870	11.870	11.880	11.890
11.890	11.890	11.910	11.910	11.920	11.930	11.950	11.950
11.960	11.960	11.960	11.960	11.950	11.960	11.960	11.960
11.960	11.950	11.950	11.940	11.960	11.980	11.990	12.010
12.030	12.040	12.050	12.050	12.050	12.050	12.050	12.050
12.040	12.060	12.060	12.070	12.070	12.070	12.070	12.060
12.070	12.070	12.080	12.080	12.080	12.090	12.090	12.080

12.080	12.080	12.080	12.080	12.090	12.100	12.100	12.100
12.100	12.100	12.110	12.110	12.120	12.130	12.130	12.130
12.130	12.140	12.140	12.130	12.130	12.130	12.110	12.100
12.070	12.060	12.070	12.080	12.090	12.100	12.110	12.110
12.120	12.060	12.010	12.030	12.040	12.050	12.050	12.060
12.060	12.050	12.040	12.030	12.020	12.020	12.020	12.020
12.010	11.990	11.980	11.940	11.940	11.930	11.930	11.920
11.910	11.900	11.900	11.900	11.900	11.900	11.910	11.900
11.880	11.870	11.870	11.860	11.860	11.850	11.860	11.860
11.850	11.850	11.850	11.860	11.860	11.870	11.860	11.860
11.850	11.840	11.850	11.850	11.870	11.890	11.880	11.880
11.880	11.890	11.900	11.910	11.910	11.910	11.910	11.920
11.920	11.930	11.940	11.940	11.950	11.950	11.950	11.950
11.950	11.960	11.950	11.950	11.960	11.970	11.980	11.980
11.990	12.000	12.000	11.990	11.990	11.990	12.000	12.000
12.010	12.020	12.020	12.030	12.040	12.050	12.060	12.060
12.060	12.060	12.060	12.060	12.060	12.060	12.070	12.080
12.090	12.100	12.090	12.120	12.130	12.140	12.130	12.140
12.140	12.140	12.150	12.150	12.160	12.160	12.170	12.170
12.170	12.150	12.140	12.130	12.120	12.110	12.100	12.090
12.090	12.090	12.080	12.070	12.070	12.060	12.050	12.030
12.030	12.020	12.010	12.020	12.010	12.010	12.010	12.010
12.020	12.020	12.010	12.000	12.000	11.980	11.970	11.970
11.960	11.960	11.960	11.960	11.950			

Note: The National Aeronautics and Space Administration (NASA) Report CR-119 identifies an elevation of 10.97 inches at 1620 feet. This is considered a typographical error and has been corrected in this table. The elevation is 10.87 inches.

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revised 12-16-97: JT editorial changes
revised 7-22-98: Incorporates ANM-7 changes (no directorate comments were incorporated)

Recommendation Letter

400 Main Street
East Hartford, Connecticut 06108

Pratt & Whitney
A United Technologies Company

June 1, 2000

Department of Transportation
Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591

Attention: Mr. Anthony Fazio, ARM-1

Subject: ARAC Disposition of Public Comments

Reference: ARAC tasking, Federal Aviation Administration letter to TAEIG, dated February 8, 2000.

Dear Tony,

In accordance with the reference tasking, the ARAC Transport Airplane and Engine Issues Group is pleased to submit the following reports as ARAC recommendations for the disposition of public comments to recently published NPRM's.

- Revised Landing Gear Shock Absorption Test Requirements - ANM-98-182-A
- Taxi, Takeoff and Landing Roll Design Loads - ANM-94-461-A

These reports have been prepared by the Loads and Dynamics Harmonization Working Group of TAEIG.

Sincerely yours,

Craig R. Bolt

C. R. Bolt
Assistant Chair, TAEIG

Copy: Kris Carpenter - FAA-NWR
*Effie Upshaw - FAA-ARM-209
*Larry Hansen - Gulfstream

*letter only

CRB002_060100

Recommendation

Loads and Dynamics Harmonization Working Group

Disposition of Comments

Date: 5/19/00

Document: Proposed Advisory Circular 25.491-1, "Taxi, Takeoff and Landing Roll Design Loads"

Published: Federal Register Volume 64, No 199, dated October 15, 1999

Date comment period closed: December 14, 1999

General assessment of comments:

Several comments were received from 2 commenters (Transport Canada and the General Aviation Manufacturers Association). Because of the substantive nature of some of the comments, the FAA requested the ARAC Loads and Dynamics Working Group by letter dated February 8, 2000 to consider the comments and provide recommendations for the disposition of the comments along with any recommendations for changes to the Advisory Circular. Comments are summarized as follows along with recommended disposition.

1) Altitude temperature effects should be taken into account

The commenter was concerned with the effect of altitude and temperature on the V_{L2} speed used in the Advisory Circular. The working group disagreed that this was necessary for V_{L2} since altitude and temperature are a part of the V_{L2} definition in section 25.479. However, it was recognized that the Advisory Circular also references the speed V_R and there is no such definition for the speed in the FAR. Therefore, the HWG recommends that the words (..defined at maximum altitude and temperature) be inserted after V_R in the Advisory Circular. (See attached draft)

2) The Ground Vibration test and Landing Gear drop tests should be referenced.

The commenter suggested that the Ground Vibration tests and Landing Gear shock absorption tests be referenced in regard to the mathematical model used for the taxi load analysis and further, that the maximum structural damping levels should be prescribed. The HWG agreed that the ground vibration tests should be referenced as an acceptable validation means for the airframe dynamic model but the group disagree that the Advisory Circular should set a specific upper limit on the damping values that are allowed to be used in the analysis different values could be appropriate if justified by test experience. (See attached draft)

3) Provide guidelines for the speed increment to be used.

The commenter suggested that the Advisory Circular provide guidelines for speed increments to be used for the "constant speed runs" prescribed by the advisory circular.

The basic objective is that the constant speed run that produces the peak loads should be searched for, and this can only be done by using a sufficiently small increment of speed. Rather than prescribe a specific speed increment, that may no fit all airplane models, it was agreed that this basic objective be explicitly stated. The HWG agreed that AC text should be modified in this regard along with additional clarification for the reason that the speed runs be "constant" instead of accelerated. (See attached draft)

4) Light weight conditions should also be investigated.

The commenter was concerned that lighter weights can produce higher load factors. While the HWG understand that higher load factors can result from lighter weights, these conditions will not result in critical design loads for the aircraft as other design conditions such as for gust and landing impact will provide higher loads. The HWG believes that adding additional weight conditions would result in additional analysis with no added value. No change in the weight conditions is proposed.

5) AC should differentiate between trimable and untrimable stabilizers.

The commenter was pointing out that paragraph 4d of the AC uses language that is applicable to only one kind of stabilizer. The HWG agree and it was agreed to change the second sentence by removing "set within the appropriate green band" with "at the appropriate". Also the text "relative to the stabilizer" would be added after the word "faired" in the last sentence of this paragraph. (See attached draft)

6) Combined load condition in paragraph 6 should be better defined.

The commenter was concerned that there needed to be a more precise definition for the combined load condition prescribed by paragraph 6. The commenter provided some suggestions for combinations to consider. The HWG agreed with the commenter that a better definition was needed. The HWG proposes to add the following text into paragraph 6. "drag load of 20% of the vertical load and a side load of 20% of the vertical load. Side load acting in either direction should be considered." (See attached draft)

Conclusion:

The HWG has addressed all the public comments and proposes changes as marked in the attached draft.

Revised Advisory Circular Attached.

Revised 8 Feb2000 in Phoenix

U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

TAXI, TAKEOFF AND LANDING ROLL DESIGN LOADS

Date: Rev ~~26 May 1999~~ 8Feb 2000
Initiated by: ANM-110

AC No. 25.491-1
Change:

1. PURPOSE. This advisory circular (AC) sets forth acceptable methods of compliance with the provisions of part 25 of the Federal Aviation Regulations (FAR) dealing with the certification requirements for taxi, takeoff and landing roll design loads. Guidance information is provided for showing compliance with § 25.491 of the FAR, relating to structural design for airplane operation on paved runways and taxiways normally used in commercial operations. Other methods of compliance with the requirements may be acceptable.

2. RELATED FAR SECTIONS. The contents of this AC are considered by the Federal Aviation Administration (FAA) in determining compliance with § 25.491 of the FAR. Related sections are §§ 25.305(c) and 25.235.

3. BACKGROUND.

a. All paved runways and taxiways have an inherent degree of surface unevenness, or roughness. This is the result of the normal tolerances of engineering standards required for construction, as well as the result of events such as uneven settlement and frost heave. In addition, repair of surfaces on an active runway or taxiway can result in temporary ramped surfaces. Many countries have developed criteria for runway surface roughness. The International Civil Aviation Organization (ICAO) standards are published in ICAO Annex 14.

b. In the late 1940's, as airplanes became larger, more flexible, and operated at higher ground speeds, consideration of dynamic loads during taxi, landing rollout, and takeoff became important in airplane design. The Civil Aeronautics Administration, in Civil Air Regulations 4b (CAR 4b), § 4b.172, required the effects of landing gear deflection during taxiing over the roughest ground expected in service to be considered relative to its effect on damage to structural components. The CAR 4b, § 4b.235, also required the airplane be designed, in part, to withstand loads calculated under § 4b.172. Those regulations were carried over to part 25 of the FAR as § 25.235 and § 25.491 respectively. Substantiation of the effect of ground loads on flexible structure is required by § 25.305(c).

c. Several approaches had been taken by different manufacturers in complying with the noted regulations. If dynamic effects due to rigid body modes or airframe flexibility during taxi were not considered critical, some manufacturers used a simplified static analysis where a static inertia force was applied to the airplane using a load factor of 2.0 for single axle gears or 1.7 for multiple axle gears. The lower 1.7 factor was justified based on an assumption that there was a load alleviating effect resulting from rotation of the beam, on which the forward and aft axles are attached, about the central pivot point on the strut. The static load factor approach was believed to encompass any dynamic effects and it had the benefit of a relatively simple analysis.

d. As computers became more powerful and dynamic analysis methods became more sophisticated, it was found that dynamic effects sometimes resulted in loads greater than those which were predicted by the static criterion. Some manufacturers performed calculations using a series of harmonic bumps to represent a runway surface, tuning the bumps to excite various portions of the structure at a given speed. U.S. Military Standard 8862 defines amplitude and wavelengths of 1-cosine bumps intended to excite low speed plunge, pitch and wing first bending modes.

e. Some manufacturers used actual runway profile data to calculate loads. The runway profiles of the San Francisco Runway 28R or Anchorage Runway 24, which were known to cause high loads on airplanes and were the subject of pilot complaints until resurfaced, have been used in a series of bi-directional constant speed analytical runs to determine loads. In some cases, accelerated runs have been used, starting from several points along the runway. The profiles of those runways are described in NASA Reports CR-119 and TN D-5703. Such deterministic dynamic analyses have in general proved to be satisfactory.

f. Some manufacturers have used a statistical power spectral density (PSD) approach, especially to calculate fatigue loads. Extensive PSD runway roughness data exist for numerous world runways. The PSD approach is not considered practical for calculation of limit loads, ~~due to difficulties in simulating the non-linearities in the landing gear shock absorption features.~~

g. Because the various methods described above produce different results, the guidance information given in paragraphs 4, 5, and 6 of this AC should be used when demonstrating compliance with § 25.491.

4. RUNWAY PROFILE CONDITION.

a. Consideration of airframe flexibility and landing gear dynamic characteristics is necessary in most cases. A deterministic dynamic analysis, based on the San Francisco Runway 28R (before it was resurfaced), described in Table 1 of this AC, is an acceptable method for compliance. As an alternative means of compliance, the San Francisco Runway 28R (before it was resurfaced) may be used with the severe bump from 1530 to 1538 feet modified per Table 2. The modifications to the bump reflect the maximum slope change permitted in ICAO Annex 14 for temporary ramps used to transition asphalt overlays to existing pavement. The points affected by this modification are outlined in Table 1.

b. Airplane design loads should be developed for the most critical conditions arising from taxi, takeoff, and landing run. The airplane analysis model should include significant airplane rigid body and flexible modes, and the appropriate landing gear and tire characteristics. Unless the airplane has design features that would result in significant asymmetric loads, only the symmetric cases need be investigated.

c. Airplane steady aerodynamic effects should normally be included. However, they may be ignored if their deletion is shown to produce conservative loads. Unsteady aerodynamic effects on dynamic response may be neglected.

d. Conditions should be run at the maximum takeoff weight and the maximum landing weight with critical combinations of wing fuel, payload, and extremes of center of gravity (c.g.) range. For airplanes with trimable stabilizers, the stabilizer should be ~~set within the appropriate green band~~at the appropriate setting for takeoff cases and at the recommended final approach setting for landing cases. The elevator should be assumed faired relative to the stabilizer throughout the takeoff or landing run, unless other normal procedures are specified in the flight manual.

e. A series of constant speed runs should be made in both directions from 20 knots up to the maximum ground speeds expected in normal operation (V_R defined at maximum altitude and temperature for takeoff conditions, 1.25 V_{L2} for landing conditions). Sufficiently small speed increments should be evaluated to assure that maximum loads are achieved. Constant speed runs should be made because ~~Using~~ using ~~only~~ accelerated runs ~~is not recommended~~ may not define ~~due to the possibility that~~ the speed/roughness points which could produce peak dynamic loads ~~could be missed~~. For maximum take-off weight cases, the analysis should account for normal takeoff flap and control settings and consider both zero and maximum thrust. For maximum landing weight cases, the analysis should account for normal flap and spoiler positions following landing, and steady pitching moments equivalent to those produced by braking with a coefficient of friction of 0.3 with and without reverse thrust. The effects of automatic braking systems that reduce braking in the presence of reverse thrust may be taken into account.

5. DISCRETE LOAD CONDITION. One of the following discrete limit load conditions should be evaluated:

a. With all landing gears in contact with the ground, the condition of a vertical load equal to 1.7 times the static ground reaction should be investigated under the most adverse airplane loading distribution at maximum takeoff weight, with and without thrust from the engines;

b. As an alternative to paragraph 5(a) above, it would be acceptable to undertake dynamic analyses under the same conditions considered in paragraph 4 of this AC considering the aircraft response to each of the following pairs of identical and contiguous 1-cosine upwards bumps on an otherwise smooth runway:

(i) Bump wavelengths equal to the mean longitudinal distance between nose and main landing gears, or between the main and tail landing gears, as appropriate; and separately.

(ii) Bump wavelengths equal to twice this distance.

The bump height in each case should be defined as:

$$H = 1.2 + 0.023\sqrt{L}$$

Where--

H = the bump height (inches)

L = the bump wavelength (inches)

6. COMBINED LOAD CONDITION. A condition of combined vertical, side and drag loads should be investigated for the main landing gear. In the absence of a more rational analysis a vertical load equal to 90% of the ground reaction from paragraph 5 above should be combined with a drag load of 20% of the vertical load and a side load of 20% of the vertical load. Side loads acting either direction should be considered.

7. TIRE CONDITIONS. The calculation of maximum gear loads in accordance with paragraphs 4, 5, and 6, may be performed using fully inflated tires. For multiple wheel units, the maximum gear loads should be distributed between the wheels in accordance with the criteria of § 25.511.

TABLE 1

SAN FRANCISCO RUNWAY 28R

ONE TRACK
LENGTH: 3880 FEET
NUMBER OF POINTS: 1941
POINT SPACING: 2 FEET
ELEVATIONS: FEET
REFERENCE SOURCE: REPORT TO NASA (EFFECTS OF RUNWAY UNEVENNESS ON THE DYNAMIC RESPONSE OF SUPERSONIC TRANSPORTS), JULY 1964, U. OF CALIF. BERKLEY.
RUNWAY ELEVATION POINTS IN FEET (READ ROW WISE):

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
0.00	10.30	2.00	10.31	4.00	10.30	6.00	10.30	8.00	10.31	10.00	10.32	12.00	10.33	14.00	10.34
16.00	10.35	18.00	10.36	20.00	10.36	22.00	10.37	24.00	10.37	26.00	10.37	28.00	10.38	30.00	10.39
32.00	10.40	34.00	10.40	36.00	10.41	38.00	10.41	40.00	10.42	42.00	10.43	44.00	10.43	46.00	10.44
48.00	10.44	50.00	10.44	52.00	10.44	54.00	10.44	56.00	10.45	58.00	10.46	60.00	10.47	62.00	10.47
64.00	10.48	66.00	10.49	68.00	10.49	70.00	10.50	72.00	10.50	74.00	10.50	76.00	10.50	78.00	10.50
80.00	10.50	82.00	10.49	84.00	10.49	86.00	10.49	88.00	10.49	90.00	10.50	92.00	10.50	94.00	10.51
96.00	10.51	98.00	10.52	100.00	10.52	102.00	10.52	104.00	10.53	106.00	10.53	108.00	10.54	110.00	10.54
112.00	10.55	114.00	10.55	116.00	10.55	118.00	10.55	120.00	10.54	122.00	10.55	124.00	10.55	126.00	10.56
128.00	10.57	130.00	10.57	132.00	10.57	134.00	10.57	136.00	10.57	138.00	10.58	140.00	10.57	142.00	10.57
144.00	10.58	146.00	10.57	148.00	10.56	150.00	10.56	152.00	10.56	154.00	10.56	156.00	10.56	158.00	10.56
160.00	10.56	162.00	10.56	164.00	10.55	166.00	10.55	168.00	10.55	170.00	10.56	172.00	10.57	174.00	10.57
176.00	10.57	178.00	10.57	180.00	10.56	182.00	10.55	184.00	10.55	186.00	10.55	188.00	10.55	190.00	10.55
192.00	10.56	194.00	10.56	196.00	10.56	198.00	10.56	200.00	10.55	202.00	10.54	204.00	10.53	206.00	10.52
208.00	10.52	210.00	10.52	212.00	10.52	214.00	10.52	216.00	10.52	218.00	10.53	220.00	10.52	222.00	10.52
224.00	10.51	226.00	10.52	228.00	10.52	230.00	10.51	232.00	10.52	234.00	10.52	236.00	10.53	238.00	10.53
240.00	10.53	242.00	10.53	244.00	10.53	246.00	10.53	248.00	10.53	250.00	10.53	252.00	10.53	254.00	10.52
256.00	10.53	258.00	10.54	260.00	10.54	262.00	10.54	264.00	10.54	266.00	10.54	268.00	10.54	270.00	10.55
272.00	10.55	274.00	10.54	276.00	10.55	278.00	10.55	280.00	10.58	282.00	10.57	284.00	10.58	286.00	10.59
288.00	10.60	290.00	10.61	292.00	10.62	294.00	10.63	296.00	10.65	298.00	10.66	300.00	10.66	302.00	10.67
304.00	10.66	306.00	10.67	308.00	10.67	310.00	10.67	312.00	10.67	314.00	10.67	316.00	10.66	318.00	10.66
320.00	10.65	322.00	10.65	324.00	10.65	326.00	10.65	328.00	10.66	330.00	10.67	332.00	10.67	334.00	10.67
336.00	10.68	338.00	10.68	340.00	10.68	342.00	10.69	344.00	10.69	346.00	10.69	348.00	10.70	350.00	10.71
352.00	10.71	354.00	10.72	356.00	10.72	358.00	10.71	360.00	10.72	362.00	10.72	364.00	10.72	366.00	10.71
368.00	10.72	370.00	10.72	372.00	10.73	374.00	10.73	376.00	10.74	378.00	10.75	380.00	10.75	382.00	10.76
384.00	10.77	386.00	10.78	388.00	10.79	390.00	10.80	392.00	10.81	394.00	10.81	396.00	10.82	398.00	10.83
400.00	10.84	402.00	10.85	404.00	10.86	406.00	10.86	408.00	10.86	410.00	10.86	412.00	10.85	414.00	10.86
416.00	10.86	418.00	10.87	420.00	10.87	422.00	10.87	424.00	10.87	426.00	10.87	428.00	10.86	430.00	10.85
432.00	10.84	434.00	10.84	436.00	10.83	438.00	10.83	440.00	10.84	442.00	10.85	444.00	10.86	446.00	10.87
448.00	10.87	450.00	10.88	452.00	10.89	454.00	10.90	456.00	10.92	458.00	10.93	460.00	10.94	462.00	10.95

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
464.00	10.95	466.00	10.95	468.00	10.95	470.00	10.95	472.00	10.95	474.00	10.96	476.00	10.97	478.00	10.98
480.00	10.98	482.00	10.99	484.00	10.99	486.00	10.99	488.00	11.00	490.00	11.01	492.00	11.01	494.00	11.01
496.00	11.01	498.00	10.98	500.00	10.96	502.00	10.95	504.00	10.95	506.00	10.95	508.00	10.96	510.00	10.97
512.00	10.97	514.00	10.98	516.00	10.97	518.00	10.97	520.00	10.98	522.00	10.99	524.00	11.00	526.00	11.01
528.00	11.03	530.00	11.03	532.00	11.03	534.00	11.03	536.00	11.03	538.00	11.03	540.00	11.03	542.00	11.03
544.00	11.02	546.00	11.02	548.00	11.03	550.00	11.04	552.00	11.05	554.00	11.05	556.00	11.04	558.00	11.06
560.00	11.07	562.00	11.07	564.00	11.08	566.00	11.08	568.00	11.09	570.00	11.10	572.00	11.12	574.00	11.13
576.00	11.14	578.00	11.14	580.00	11.15	582.00	11.16	584.00	11.17	586.00	11.17	588.00	11.17	590.00	11.17
592.00	11.17	594.00	11.18	596.00	11.18	598.00	11.18	600.00	11.17	602.00	11.17	604.00	11.17	606.00	11.17
608.00	11.19	610.00	11.17	612.00	11.18	614.00	11.18	616.00	11.18	618.00	11.19	620.00	11.19	622.00	11.19
624.00	11.20	626.00	11.21	628.00	11.21	630.00	11.21	632.00	11.20	634.00	11.20	636.00	11.20	638.00	11.19
640.00	11.18	642.00	11.18	644.00	11.17	646.00	11.16	648.00	11.15	650.00	11.14	652.00	11.14	654.00	11.14
656.00	11.12	658.00	11.11	660.00	11.09	662.00	11.09	664.00	11.09	666.00	11.09	668.00	11.09	670.00	11.09
672.00	11.09	674.00	11.09	676.00	11.09	678.00	11.09	680.00	11.09	682.00	11.09	684.00	11.09	686.00	11.08
688.00	11.08	690.00	11.08	692.00	11.08	694.00	11.07	696.00	11.06	698.00	11.05	700.00	11.04	702.00	11.03
704.00	11.02	706.00	11.01	708.00	11.00	710.00	10.99	712.00	10.99	714.00	10.98	716.00	10.99	718.00	10.98
720.00	10.98	722.00	10.98	724.00	10.98	726.00	10.98	728.00	10.98	730.00	10.99	732.00	10.99	734.00	11.00
736.00	11.00	738.00	11.00	740.00	11.00	742.00	11.00	744.00	11.01	746.00	11.02	748.00	11.02	750.00	11.02
752.00	11.02	754.00	11.02	756.00	11.02	758.00	11.01	760.00	11.01	762.00	11.00	764.00	11.00	766.00	11.00
768.00	11.00	770.00	11.00	772.00	11.00	774.00	10.99	776.00	10.99	778.00	10.98	780.00	10.99	782.00	10.99
784.00	11.00	786.00	11.01	788.00	11.01	790.00	11.01	792.00	11.03	794.00	11.04	796.00	11.03	798.00	11.05
800.00	11.06	802.00	11.07	804.00	11.06	806.00	11.07	808.00	11.08	810.00	11.08	812.00	11.08	814.00	11.09
816.00	11.09	818.00	11.08	820.00	11.08	822.00	11.08	824.00	11.08	826.00	11.08	828.00	11.08	830.00	11.07
832.00	11.08	834.00	11.08	836.00	11.08	838.00	11.08	840.00	11.09	842.00	11.08	844.00	11.08	846.00	11.07
848.00	11.07	850.00	11.06	852.00	11.05	854.00	11.05	856.00	11.04	858.00	11.05	860.00	11.04	862.00	11.04
864.00	11.04	866.00	11.04	868.00	11.04	870.00	11.04	872.00	11.04	874.00	11.03	876.00	11.03	878.00	11.03
880.00	11.03	882.00	11.02	884.00	11.02	886.00	11.02	888.00	11.02	890.00	11.02	892.00	11.02	894.00	11.03
896.00	11.03	898.00	11.04	900.00	11.05	902.00	11.05	904.00	11.06	906.00	11.06	908.00	11.06	910.00	11.07
912.00	11.07	914.00	11.07	916.00	11.07	918.00	11.07	920.00	11.08	922.00	11.08	924.00	11.07	926.00	11.07
928.00	11.07	930.00	11.06	932.00	11.06	934.00	11.06	936.00	11.06	938.00	11.06	940.00	11.07	942.00	11.07
944.00	11.08	946.00	11.08	948.00	11.09	950.00	11.09	952.00	11.09	954.00	11.09	956.00	11.10	958.00	11.09
960.00	11.09	962.00	11.09	964.00	11.09	966.00	11.08	968.00	11.08	970.00	11.07	972.00	11.07	974.00	11.06
976.00	11.07	978.00	11.09	980.00	11.10	982.00	11.10	984.00	11.11	986.00	11.11	988.00	11.12	990.00	11.12
992.00	11.12	994.00	11.11	996.00	11.11	998.00	11.11	1000.00	11.11	1002.00	11.11	1004.00	11.10	1006.00	11.11
1008.00	11.11	1010.00	11.12	1012.00	11.12	1014.00	11.12	1016.00	11.11	1018.00	11.11	1020.00	11.12	1022.00	11.11
1024.00	11.11	1026.00	11.11	1028.00	11.10	1030.00	11.10	1032.00	11.12	1034.00	11.13	1036.00	11.15	1038.00	11.16
1040.00	11.17	1042.00	11.18	1044.00	11.18	1046.00	11.19	1048.00	11.19	1050.00	11.20	1052.00	11.22	1054.00	11.22
1056.00	11.23	1058.00	11.23	1060.00	11.23	1062.00	11.24	1064.00	11.25	1066.00	11.25	1068.00	11.26	1070.00	11.24
1072.00	11.27	1074.00	11.28	1076.00	11.28	1078.00	11.30	1080.00	11.31	1082.00	11.32	1084.00	11.33	1086.00	11.34
1088.00	11.34	1090.00	11.34	1092.00	11.34	1094.00	11.33	1096.00	11.32	1098.00	11.32	1100.00	11.31	1102.00	11.32
1104.00	11.32	1106.00	11.31	1108.00	11.31	1110.00	11.31	1112.00	11.32	1114.00	11.31	1116.00	11.32	1118.00	11.33
1120.00	11.34	1122.00	11.35	1124.00	11.35	1126.00	11.36	1128.00	11.36	1130.00	11.36	1132.00	11.37	1134.00	11.37
1136.00	11.37	1138.00	11.37	1140.00	11.38	1142.00	11.38	1144.00	11.38	1146.00	11.38	1148.00	11.38	1150.00	11.38
1152.00	11.38	1154.00	11.38	1156.00	11.38	1158.00	11.37	1160.00	11.37	1162.00	11.37	1164.00	11.37	1166.00	11.38
1168.00	11.38	1170.00	11.39	1172.00	11.38	1174.00	11.38	1176.00	11.39	1178.00	11.40	1180.00	11.41	1182.00	11.41
1184.00	11.42	1186.00	11.43	1188.00	11.44	1190.00	11.44	1192.00	11.45	1194.00	11.46	1196.00	11.46	1198.00	11.46

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
1200.00	11.46	1202.00	11.47	1204.00	11.48	1206.00	11.48	1208.00	11.48	1210.00	11.49	1212.00	11.50	1214.00	11.50
1216.00	11.50	1218.00	11.50	1220.00	11.50	1222.00	11.50	1224.00	11.49	1226.00	11.49	1228.00	11.49	1230.00	11.48
1232.00	11.47	1234.00	11.46	1236.00	11.46	1238.00	11.46	1240.00	11.46	1242.00	11.47	1244.00	11.47	1246.00	11.47
1248.00	11.47	1250.00	11.46	1252.00	11.45	1254.00	11.45	1256.00	11.45	1258.00	11.46	1260.00	11.46	1262.00	11.46
1264.00	11.45	1266.00	11.45	1268.00	11.45	1270.00	11.45	1272.00	11.45	1274.00	11.46	1276.00	11.46	1278.00	11.46
1280.00	11.48	1282.00	11.47	1284.00	11.47	1286.00	11.48	1288.00	11.48	1290.00	11.48	1292.00	11.48	1294.00	11.49
1296.00	11.49	[illegible]	11.50	1300.00	11.51	1302.00	11.52	1304.00	11.52	1306.00	11.52	1308.00	11.52	1310.00	11.52
1312.00	11.52	[illegible]	11.52	1316.00	11.53	1318.00	11.52	1320.00	11.52	1322.00	11.52	1324.00	11.53	1326.00	11.53
1328.00	11.53	[illegible]	11.53	1332.00	11.53	1334.00	11.53	1336.00	11.54	1338.00	11.53	1340.00	11.52	1342.00	11.52
1344.00	11.51	[illegible]	11.53	1348.00	11.52	1350.00	11.54	1352.00	11.53	1354.00	11.54	1356.00	11.53	1358.00	11.54
1360.00	11.53	1362.00	11.54	1364.00	11.55	1366.00	11.54	1368.00	11.54	1370.00	11.54	1372.00	11.54	1374.00	11.53
1376.00	11.52	1378.00	11.51	1380.00	11.50	1382.00	11.49	1384.00	11.49	1386.00	11.49	1388.00	11.49	1390.00	11.49
1392.00	11.48	1394.00	11.47	1396.00	11.47	1398.00	11.47	1400.00	11.46	1402.00	11.47	1404.00	11.47	1406.00	11.48
1408.00	11.47	1410.00	11.46	1412.00	11.46	1414.00	11.46	1416.00	11.46	1418.00	11.46	1420.00	11.47	1422.00	11.47
1424.00	11.47	1426.00	11.48	1428.00	11.46	1430.00	11.44	1432.00	11.43	1434.00	11.41	1436.00	11.40	1438.00	11.39
1440.00	11.38	1442.00	11.37	1444.00	11.36	1446.00	11.36	1448.00	11.35	1450.00	11.35	1452.00	11.35	1454.00	11.35
1456.00	11.35	1458.00	11.34	1460.00	11.34	1462.00	11.33	1464.00	11.32	1466.00	11.32	1468.00	11.32	1470.00	11.31
1472.00	11.31	1474.00	11.30	1476.00	11.29	1478.00	11.29	1480.00	11.28	1482.00	11.28	1484.00	11.28	1486.00	11.28
1488.00	11.28	1490.00	11.27	1492.00	11.27	1494.00	11.27	1496.00	11.26	1498.00	11.26	1500.00	11.25	1502.00	11.25
1504.00	11.24	1506.00	11.23	1508.00	11.22	1510.00	11.21	1512.00	11.19	1514.00	11.18	1516.00	11.17	1518.00	11.17
1520.00	11.15	1522.00	11.13	1524.00	11.12	1526.00	11.10	1528.00	11.10	1530.00	11.18	1532.00	11.17	1534.00	11.14
1536.00	11.14	1538.00	11.12	1540.00	11.00	1542.00	10.97	1544.00	10.95	1546.00	10.94	1548.00	10.92	1550.00	10.91
1552.00	10.92	1554.00	10.92	1556.00	10.91	1558.00	10.93	1560.00	10.93	1562.00	10.93	1564.00	10.93	1566.00	10.93
1568.00	10.93	1570.00	10.93	1572.00	10.93	1574.00	10.93	1576.00	10.93	1578.00	10.93	1580.00	10.94	1582.00	10.94
1584.00	10.94	1586.00	10.94	1588.00	10.95	1590.00	10.94	1592.00	10.93	1594.00	10.94	1596.00	10.94	1598.00	10.93
1600.00	10.92	1602.00	10.92	1604.00	10.92	1606.00	10.91	1608.00	10.91	1610.00	10.91	1612.00	10.91	1614.00	10.90
1616.00	10.89	1618.00	10.88	1620.00	10.87	1622.00	10.89	1624.00	10.88	1626.00	10.86	1628.00	10.86	1630.00	10.87
1632.00	10.86	1634.00	10.85	1636.00	10.86	1638.00	10.86	1640.00	10.85	1642.00	10.85	1644.00	10.85	1646.00	10.84
1648.00	10.84	1650.00	10.84	1652.00	10.83	1654.00	10.83	1656.00	10.82	1658.00	10.82	1660.00	10.81	1662.00	10.81
1664.00	10.80	1666.00	10.79	1668.00	10.79	1670.00	10.79	1672.00	10.79	1674.00	10.79	1676.00	10.79	1678.00	10.80
1680.00	10.80	1682.00	10.81	1684.00	10.82	1686.00	10.82	1688.00	10.83	1690.00	10.84	1692.00	10.85	1694.00	10.85
1696.00	10.85	1698.00	10.87	1700.00	10.87	1702.00	10.86	1704.00	10.87	1706.00	10.86	1708.00	10.87	1710.00	10.87
1712.00	10.87	1714.00	10.87	1716.00	10.86	1718.00	10.85	1720.00	10.84	1722.00	10.84	1724.00	10.84	1726.00	10.84
1728.00	10.84	1730.00	10.83	1732.00	10.82	1734.00	10.82	1736.00	10.82	1738.00	10.82	1740.00	10.82	1742.00	10.82
1744.00	10.83	1746.00	10.82	1748.00	10.83	1750.00	10.82	1752.00	10.82	1754.00	10.82	1756.00	10.82	1758.00	10.81
1760.00	10.81	1762.00	10.81	1764.00	10.81	1766.00	10.82	1768.00	10.82	1770.00	10.82	1772.00	10.83	1774.00	10.83
1776.00	10.83	1778.00	10.84	1780.00	10.84	1782.00	10.85	1784.00	10.86	1786.00	10.86	1788.00	10.86	1790.00	10.86
1792.00	10.87	1794.00	10.86	1796.00	10.86	1798.00	10.86	1800.00	10.87	1802.00	10.87	1804.00	10.86	1806.00	10.85
1808.00	10.85	1810.00	10.89	1812.00	10.91	1814.00	10.91	1816.00	10.92	1818.00	10.92	1820.00	10.93	1822.00	10.93
1824.00	10.93	1826.00	10.94	1828.00	10.94	1830.00	10.95	1832.00	10.94	1834.00	10.93	1836.00	10.93	1838.00	10.92
1840.00	10.93	1842.00	10.91	1844.00	10.91	1846.00	10.90	1848.00	10.90	1850.00	10.90	1852.00	10.91	1854.00	10.91
1856.00	10.89	1858.00	10.90	1860.00	10.91	1862.00	10.91	1864.00	10.91	1866.00	10.92	1868.00	10.93	1870.00	10.94
1872.00	10.94	1874.00	10.94	1876.00	10.94	1878.00	10.94	1880.00	10.95	1882.00	10.93	1884.00	10.93	1886.00	10.93
1888.00	10.93	1890.00	10.92	1892.00	10.93	1894.00	10.93	1896.00	10.93	1898.00	10.93	1900.00	10.91	1902.00	10.90
1904.00	10.91	1906.00	10.91	1908.00	10.91	1910.00	10.91	1912.00	10.91	1914.00	10.91	1916.00	10.91	1918.00	10.90
1920.00	10.90	1922.00	10.89	1924.00	10.90	1926.00	10.90	1928.00	10.90	1930.00	10.91	1932.00	10.90	1934.00	10.91

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
1936.00	10.89	1938.00	10.89	1940.00	10.89	1942.00	10.89	1944.00	10.89	1946.00	10.88	1948.00	10.88	1950.00	10.87
1952.00	10.87	1954.00	10.87	1956.00	10.86	1958.00	10.88	1960.00	10.87	1962.00	10.86	1964.00	10.87	1966.00	10.87
1968.00	10.86	1970.00	10.85	1972.00	10.85	1974.00	10.85	1976.00	10.86	1978.00	10.85	1980.00	10.86	1982.00	10.86
1984.00	10.86	1986.00	10.87	1988.00	10.87	1990.00	10.87	1992.00	10.87	1994.00	10.87	1996.00	10.88	1998.00	10.87
2000.00	10.88	2002.00	10.87	2004.00	10.88	2006.00	10.88	2008.00	10.88	2010.00	10.88	2012.00	10.88	2014.00	10.89
2016.00	10.90	2018.00	10.89	2020.00	10.89	2022.00	10.89	2024.00	10.89	2026.00	10.90	2028.00	10.89	2030.00	10.89
2032.00	10.88	2034.00	10.87	2036.00	10.88	2038.00	10.87	2040.00	10.87	2042.00	10.87	2044.00	10.87	2046.00	10.88
2046.00	10.88	2050.00	10.88	2052.00	10.88	2054.00	10.88	2056.00	10.88	2058.00	10.89	2060.00	10.89	2062.00	10.89
2064.00	10.89	2066.00	10.89	2068.00	10.89	2070.00	10.89	2072.00	10.88	2074.00	10.88	2076.00	10.89	2078.00	10.88
2080.00	10.89	2082.00	10.88	2084.00	10.88	2086.00	10.88	2088.00	10.88	2090.00	10.88	2092.00	10.87	2094.00	10.87
2096.00	10.87	2098.00	10.87	2100.00	10.87	2102.00	10.88	2104.00	10.88	2106.00	10.88	2108.00	10.89	2110.00	10.89
2112.00	10.90	2114.00	10.91	2116.00	10.92	2118.00	10.92	2120.00	10.93	2122.00	10.92	2124.00	10.92	2126.00	10.92
2128.00	10.92	2130.00	10.92	2132.00	10.92	2134.00	10.92	2136.00	10.93	2138.00	10.93	2140.00	10.93	2142.00	10.93
2144.00	10.93	2146.00	10.94	2148.00	10.93	2150.00	10.93	2152.00	10.93	2154.00	10.93	2156.00	10.93	2158.00	10.92
2160.00	10.92	2162.00	10.91	2164.00	10.90	2166.00	10.92	2168.00	10.91	2170.00	10.91	2172.00	10.90	2174.00	10.90
2176.00	10.90	2178.00	10.88	2180.00	10.88	2182.00	10.86	2184.00	10.85	2186.00	10.85	2188.00	10.84	2190.00	10.84
2192.00	10.84	2194.00	10.84	2196.00	10.85	2198.00	10.85	2200.00	10.85	2202.00	10.85	2204.00	10.85	2206.00	10.85
2208.00	10.86	2210.00	10.86	2212.00	10.86	2214.00	10.87	2216.00	10.88	2218.00	10.88	2220.00	10.89	2222.00	10.90
2224.00	10.91	2226.00	10.91	2228.00	10.92	2230.00	10.92	2232.00	10.93	2234.00	10.94	2236.00	10.94	2238.00	10.95
2240.00	10.96	2242.00	10.96	2244.00	10.97	2246.00	10.99	2248.00	10.99	2250.00	10.99	2252.00	10.99	2254.00	11.00
2256.00	11.00	2258.00	11.00	2260.00	11.01	2262.00	11.01	2264.00	11.02	2266.00	11.02	2268.00	11.02	2270.00	11.04
2272.00	11.05	2274.00	11.05	2276.00	11.06	2278.00	11.08	2280.00	11.05	2282.00	11.04	2284.00	11.03	2286.00	11.03
2288.00	11.02	2290.00	11.03	2292.00	11.03	2294.00	11.04	2296.00	11.05	2298.00	11.06	2300.00	11.07	2302.00	11.09
2304.00	11.10	2306.00	11.10	2308.00	11.11	2310.00	11.12	2312.00	11.14	2314.00	11.14	2316.00	11.15	2318.00	11.16
2320.00	11.16	2322.00	11.16	2324.00	11.15	2326.00	11.15	2328.00	11.16	2330.00	11.15	2332.00	11.14	2334.00	11.14
2336.00	11.14	2338.00	11.14	2340.00	11.14	2342.00	11.14	2344.00	11.15	2346.00	11.15	2348.00	11.15	2350.00	11.15
2352.00	11.15	2354.00	11.15	2356.00	11.16	2358.00	11.16	2360.00	11.15	2362.00	11.15	2364.00	11.16	2366.00	11.16
2368.00	11.16	2370.00	11.16	2372.00	11.16	2374.00	11.16	2376.00	11.16	2378.00	11.16	2380.00	11.17	2382.00	11.17
2384.00	11.17	2386.00	11.17	2388.00	11.17	2390.00	11.17	2392.00	11.17	2394.00	11.16	2396.00	11.15	2398.00	11.15
2400.00	11.14	2402.00	11.14	2404.00	11.14	2406.00	11.13	2408.00	11.12	2410.00	11.12	2412.00	11.12	2414.00	11.12
2416.00	11.12	2418.00	11.12	2420.00	11.13	2422.00	11.13	2424.00	11.14	2426.00	11.15	2428.00	11.16	2430.00	11.17
2432.00	11.18	2434.00	11.19	2436.00	11.20	2438.00	11.20	2440.00	11.22	2442.00	11.23	2444.00	11.24	2446.00	11.24
2448.00	11.25	2450.00	11.26	2452.00	11.27	2454.00	11.28	2456.00	11.28	2458.00	11.29	2460.00	11.30	2462.00	11.30
2464.00	11.30	2466.00	11.31	2468.00	11.30	2470.00	11.31	2472.00	11.31	2474.00	11.31	2476.00	11.31	2478.00	11.30
2480.00	11.30	2482.00	11.30	2484.00	11.29	2486.00	11.29	2488.00	11.29	2490.00	11.29	2492.00	11.29	2494.00	11.29
2496.00	11.29	2498.00	11.29	2500.00	11.29	2502.00	11.30	2504.00	11.30	2506.00	11.31	2508.00	11.31	2510.00	11.32
2512.00	11.32	2514.00	11.33	2516.00	11.33	2518.00	11.34	2520.00	11.35	2522.00	11.35	2524.00	11.35	2526.00	11.35
2528.00	11.35	2530.00	11.35	2532.00	11.36	2534.00	11.36	2536.00	11.35	2538.00	11.35	2540.00	11.35	2542.00	11.35
2544.00	11.35	2546.00	11.35	2548.00	11.34	2550.00	11.34	2552.00	11.34	2554.00	11.34	2556.00	11.35	2558.00	11.35
2560.00	11.35	2562.00	11.34	2564.00	11.33	2566.00	11.33	2568.00	11.33	2570.00	11.33	2572.00	11.33	2574.00	11.33
2576.00	11.33	2578.00	11.32	2580.00	11.33	2582.00	11.33	2584.00	11.33	2586.00	11.33	2588.00	11.33	2590.00	11.34
2592.00	11.34	2594.00	11.34	2596.00	11.35	2598.00	11.35	2600.00	11.35	2602.00	11.35	2604.00	11.35	2606.00	11.35
2608.00	11.35	2610.00	11.35	2612.00	11.36	2614.00	11.36	2616.00	11.36	2618.00	11.35	2620.00	11.35	2622.00	11.35
2624.00	11.35	2626.00	11.35	2628.00	11.35	2630.00	11.36	2632.00	11.36	2634.00	11.36	2636.00	11.36	2638.00	11.36
2640.00	11.37	2642.00	11.38	2644.00	11.38	2646.00	11.39	2648.00	11.39	2650.00	11.40	2652.00	11.41	2654.00	11.42
2656.00	11.42	2658.00	11.43	2660.00	11.43	2662.00	11.42	2664.00	11.42	2666.00	11.43	2668.00	11.43	2670.00	11.43

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
2672.00	11.43	2674.00	11.43	2676.00	11.43	2678.00	11.44	2680.00	11.44	2682.00	11.45	2684.00	11.46	2686.00	11.46
2688.00	11.47	2690.00	11.48	2692.00	11.48	2694.00	11.49	2696.00	11.49	2698.00	11.50	2700.00	11.50	2702.00	11.51
2704.00	11.52	2706.00	11.52	2708.00	11.52	2710.00	11.52	2712.00	11.52	2714.00	11.52	2716.00	11.52	2718.00	11.52
2720.00	11.52	2722.00	11.52	2724.00	11.51	2726.00	11.51	2728.00	11.51	2730.00	11.50	2732.00	11.50	2734.00	11.50
2736.00	11.50	2738.00	11.51	2740.00	11.51	2742.00	11.51	2744.00	11.52	2746.00	11.52	2748.00	11.52	2750.00	11.52
2752.00	11.53	2754.00	11.53	2756.00	11.53	2758.00	11.52	2760.00	11.52	2762.00	11.52	2764.00	11.52	2766.00	11.52
2768.00	11.52	2770.00	11.53	2772.00	11.53	2774.00	11.53	2776.00	11.54	2778.00	11.53	2780.00	11.53	2782.00	11.54
2784.00	11.54	2786.00	11.54	2788.00	11.54	2790.00	11.53	2792.00	11.53	2794.00	11.53	2796.00	11.53	2798.00	11.54
2800.00	11.54	2802.00	11.54	2804.00	11.55	2806.00	11.55	2808.00	11.55	2810.00	11.56	2812.00	11.55	2814.00	11.55
2816.00	11.55	2818.00	11.55	2820.00	11.54	2822.00	11.53	2824.00	11.53	2826.00	11.53	2828.00	11.51	2830.00	11.52
2832.00	11.52	2834.00	11.53	2836.00	11.53	2838.00	11.54	2840.00	11.55	2842.00	11.56	2844.00	11.56	2846.00	11.57
2848.00	11.57	2850.00	11.57	2852.00	11.58	2854.00	11.58	2856.00	11.58	2858.00	11.58	2860.00	11.58	2862.00	11.58
2864.00	11.59	2866.00	11.59	2868.00	11.59	2870.00	11.59	2872.00	11.58	2874.00	11.57	2876.00	11.57	2878.00	11.58
2880.00	11.57	2882.00	11.57	2884.00	11.57	2886.00	11.58	2888.00	11.58	2890.00	11.59	2892.00	11.60	2894.00	11.62
2896.00	11.61	2898.00	11.61	2900.00	11.61	2902.00	11.61	2904.00	11.61	2906.00	11.62	2908.00	11.63	2910.00	11.64
2912.00	11.65	2914.00	11.66	2916.00	11.67	2918.00	11.67	2920.00	11.67	2922.00	11.68	2924.00	11.70	2926.00	11.72
2928.00	11.73	2930.00	11.74	2932.00	11.76	2934.00	11.77	2936.00	11.78	2938.00	11.80	2940.00	11.82	2942.00	11.82
2944.00	11.82	2946.00	11.83	2948.00	11.82	2950.00	11.82	2952.00	11.83	2954.00	11.84	2956.00	11.83	2958.00	11.83
2960.00	11.83	2962.00	11.83	2964.00	11.83	2966.00	11.83	2968.00	11.84	2970.00	11.85	2972.00	11.86	2974.00	11.87
2976.00	11.88	2978.00	11.88	2980.00	11.89	2982.00	11.90	2984.00	11.90	2986.00	11.90	2988.00	11.90	2990.00	11.90
2992.00	11.90	2994.00	11.91	2996.00	11.91	2998.00	11.90	3000.00	11.91	3002.00	11.91	3004.00	11.91	3006.00	11.91
3008.00	11.90	3010.00	11.91	3012.00	11.91	3014.00	11.92	3016.00	11.92	3018.00	11.92	3020.00	11.92	3022.00	11.92
3024.00	11.92	3026.00	11.92	3028.00	11.91	3030.00	11.91	3032.00	11.92	3034.00	11.91	3036.00	11.91	3038.00	11.91
3040.00	11.91	3042.00	11.90	3044.00	11.90	3046.00	11.90	3048.00	11.90	3050.00	11.90	3052.00	11.90	3054.00	11.90
3056.00	11.90	3058.00	11.90	3060.00	11.90	3062.00	11.91	3064.00	11.92	3066.00	11.92	3068.00	11.92	3070.00	11.93
3072.00	11.93	3074.00	11.93	3076.00	11.93	3078.00	11.94	3080.00	11.94	3082.00	11.95	3084.00	11.95	3086.00	11.95
3088.00	11.96	3090.00	11.96	3092.00	11.96	3094.00	11.96	3096.00	11.96	3098.00	11.96	3100.00	11.95	3102.00	11.94
3104.00	11.93	3106.00	11.92	3108.00	11.92	3110.00	11.92	3112.00	11.92	3114.00	11.92	3116.00	11.92	3118.00	11.92
3120.00	11.92	3122.00	11.92	3124.00	11.92	3126.00	11.92	3128.00	11.91	3130.00	11.90	3132.00	11.90	3134.00	11.90
3136.00	11.90	3138.00	11.90	3140.00	11.90	3142.00	11.90	3144.00	11.90	3146.00	11.90	3148.00	11.90	3150.00	11.90
3152.00	11.90	3154.00	11.90	3156.00	11.90	3158.00	11.90	3160.00	11.90	3162.00	11.89	3164.00	11.88	3166.00	11.88
3168.00	11.87	3170.00	11.87	3172.00	11.86	3174.00	11.86	3176.00	11.85	3178.00	11.85	3180.00	11.84	3182.00	11.84
3184.00	11.84	3186.00	11.84	3188.00	11.84	3190.00	11.85	3192.00	11.87	3194.00	11.89	3196.00	11.89	3198.00	11.90
3200.00	11.89	3202.00	11.92	3204.00	11.95	3206.00	11.95	3208.00	11.95	3210.00	11.94	3212.00	11.94	3214.00	11.93
3216.00	11.92	3218.00	11.92	3220.00	11.91	3222.00	11.90	3224.00	11.90	3226.00	11.89	3228.00	11.88	3230.00	11.87
3232.00	11.86	3234.00	11.85	3236.00	11.84	3238.00	11.84	3240.00	11.84	3242.00	11.83	3244.00	11.82	3246.00	11.82
3248.00	11.81	3250.00	11.83	3252.00	11.83	3254.00	11.83	3256.00	11.84	3258.00	11.84	3260.00	11.84	3262.00	11.84
3264.00	11.82	3266.00	11.83	3268.00	11.82	3270.00	11.83	3272.00	11.83	3274.00	11.84	3276.00	11.84	3278.00	11.84
3280.00	11.85	3282.00	11.84	3284.00	11.84	3286.00	11.84	3288.00	11.85	3290.00	11.85	3292.00	11.85	3294.00	11.86
3296.00	11.86	3298.00	11.84	3300.00	11.84	3302.00	11.84	3304.00	11.84	3306.00	11.84	3308.00	11.84	3310.00	11.84
3312.00	11.84	3314.00	11.84	3316.00	11.84	3318.00	11.84	3320.00	11.84	3322.00	11.83	3324.00	11.83	3326.00	11.83
3328.00	11.82	3330.00	11.83	3332.00	11.83	3334.00	11.83	3336.00	11.82	3338.00	11.82	3340.00	11.83	3342.00	11.82
3344.00	11.83	3346.00	11.83	3348.00	11.84	3350.00	11.84	3352.00	11.83	3354.00	11.83	3356.00	11.83	3358.00	11.83
3360.00	11.83	3362.00	11.84	3364.00	11.84	3366.00	11.84	3368.00	11.85	3370.00	11.85	3372.00	11.85	3374.00	11.85
3376.00	11.84	3378.00	11.84	3380.00	11.85	3382.00	11.85	3384.00	11.86	3386.00	11.86	3388.00	11.87	3390.00	11.87
3392.00	11.87	3394.00	11.87	3396.00	11.87	3398.00	11.86	3400.00	11.87	3402.00	11.87	3404.00	11.88	3406.00	11.89

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
3408.00	11.89	3410.00	11.89	3412.00	11.91	3414.00	11.91	3416.00	11.92	3418.00	11.93	3420.00	11.95	3422.00	11.95
3424.00	11.96	3426.00	11.96	3428.00	11.96	3430.00	11.96	3432.00	11.95	3434.00	11.96	3436.00	11.96	3438.00	11.96
3440.00	11.96	3442.00	11.95	3444.00	11.95	3446.00	11.94	3448.00	11.96	3450.00	11.96	3452.00	11.99	3454.00	12.01
3456.00	12.03	3458.00	12.04	3460.00	12.05	3462.00	12.05	3464.00	12.05	3466.00	12.05	3468.00	12.05	3470.00	12.05
3472.00	12.04	3474.00	12.06	3476.00	12.06	3478.00	12.07	3480.00	12.07	3482.00	12.07	3484.00	12.07	3486.00	12.06
3488.00	12.07	3490.00	12.07	3492.00	12.08	3494.00	12.08	3496.00	12.08	3498.00	12.09	3500.00	12.09	3502.00	12.08
3504.00	12.08	[illegible]	12.08	3508.00	12.08	3510.00	12.08	3512.00	12.09	3514.00	12.10	3516.00	12.10	3518.00	12.10
3520.00	12.10	[illegible]	12.10	3524.00	12.11	3526.00	12.11	3528.00	12.12	3530.00	12.13	3532.00	12.13	3534.00	12.13
3536.00	12.13	[illegible]	12.14	3540.00	12.14	3542.00	12.13	3544.00	12.13	3546.00	12.13	3548.00	12.11	3550.00	12.10
3552.00	12.07	[illegible]	12.06	3556.00	12.07	3558.00	12.06	3560.00	12.09	3562.00	12.10	3564.00	12.11	3566.00	12.11
3568.00	12.12	3570.00	12.06	3572.00	12.01	3574.00	12.03	3576.00	12.04	3578.00	12.05	3580.00	12.05	3582.00	12.06
3584.00	12.06	[illegible]	12.05	3588.00	12.04	3590.00	12.03	3592.00	12.02	3594.00	12.02	3596.00	12.02	3598.00	12.02
3600.00	12.01	3602.00	11.99	3604.00	11.98	3606.00	11.94	3608.00	11.94	3610.00	11.93	3612.00	11.93	3614.00	11.92
3616.00	11.91	3618.00	11.90	3620.00	11.90	3622.00	11.90	3624.00	11.90	3626.00	11.90	3628.00	11.91	3630.00	11.90
3632.00	11.88	3634.00	11.87	3636.00	11.87	3638.00	11.88	3640.00	11.86	3642.00	11.85	3644.00	11.86	3646.00	11.86
3648.00	11.85	3650.00	11.85	3652.00	11.85	3654.00	11.86	3656.00	11.86	3658.00	11.87	3660.00	11.86	3662.00	11.86
3664.00	11.85	3666.00	11.84	3668.00	11.85	3670.00	11.85	3672.00	11.87	3674.00	11.89	3676.00	11.88	3678.00	11.88
3680.00	11.88	3682.00	11.89	3684.00	11.90	3686.00	11.91	3688.00	11.91	3690.00	11.91	3692.00	11.91	3694.00	11.92
3696.00	11.92	3698.00	11.93	3700.00	11.94	3702.00	11.94	3704.00	11.95	3706.00	11.95	3708.00	11.95	3710.00	11.95
3712.00	11.95	3714.00	11.96	3716.00	11.95	3718.00	11.95	3720.00	11.96	3722.00	11.97	3724.00	11.98	3726.00	11.98
3728.00	11.99	3730.00	12.00	3732.00	12.00	3734.00	11.99	3736.00	11.99	3738.00	11.99	3740.00	12.00	3742.00	12.00
3744.00	12.01	3746.00	12.02	3748.00	12.02	3750.00	12.03	3752.00	12.04	3754.00	12.05	3756.00	12.06	3758.00	12.06
3760.00	12.06	3762.00	12.06	3764.00	12.06	3766.00	12.06	3768.00	12.06	3770.00	12.06	3772.00	12.07	3774.00	12.08
3776.00	12.09	3778.00	12.10	3780.00	12.09	3782.00	12.12	3784.00	12.13	3786.00	12.14	3788.00	12.13	3790.00	12.14
3792.00	12.14	3794.00	12.14	3796.00	12.15	3798.00	12.15	3800.00	12.16	3802.00	12.16	3804.00	12.17	3806.00	12.17
3808.00	12.17	3810.00	12.15	3812.00	12.14	3814.00	12.13	3816.00	12.12	3818.00	12.11	3820.00	12.10	3822.00	12.09
3824.00	12.09	3826.00	12.09	3828.00	12.08	3830.00	12.07	3832.00	12.07	3834.00	12.06	3836.00	12.05	3838.00	12.03
3840.00	12.03	3842.00	12.02	3844.00	12.01	3846.00	12.02	3848.00	12.01	3850.00	12.01	3852.00	12.01	3854.00	12.01
3856.00	12.02	3858.00	12.02	3860.00	12.01	3862.00	12.00	3864.00	12.00	3866.00	11.98	3868.00	11.97	3870.00	11.97
3872.00	11.96	3874.00	11.96	3876.00	11.96	3878.00	11.96	3880.00	11.95						

*The National Aeronautics and Space Administration (NASA) Report CR-119 identifies an elevation of 10.97 inches at 1620 feet. This is considered a typographical error and has been corrected in Table 1. The elevation is 10.87 inches.

TABLE 2

SF28R SEVERE BUMP MODIFICATIONS
PER ICAO ANNEX 14, SPECIFICATION 9.4.15

Distance	Original Elevation (ft)	Modified Elevation (ft)
1530	11.18	11.10
1532	11.17	11.11
1534	11.14	11.11
1536	11.14	11.07
1538	11.12	11.04

FAA Action

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

Proposed Advisory Circular 25.491–1, Taxi, Takeoff and Landing Roll Design Loads

AGENCY: Federal Aviation Administration, DOT.

ACTION: Notice of availability of proposed Advisory Circular (AC) 25.491–1, and request for comments.

SUMMARY: This notice announces the availability of and requests comments on a proposed advisory circular (AC) which sets forth acceptable methods of compliance with 14 CFR 25.491 concerning taxi, takeoff and landing roll design loads. This notice is necessary to give all interested persons an opportunity to present their views on the proposed AC.

DATES: Comments must be received on or before December 14, 1999.

ADDRESSES: Send all comments on proposed AC to: Federal Aviation Administration, Attention: James D. Haynes, Airframe and Cabin Safety Branch, ANM–115, Transport Airplane Directorate, Aircraft Certification Service, 1601 Lind Avenue SW, Renton, WA 98055–4056. Comments may be inspected at the above address between 7:30 a.m. and 4:00 p.m. weekdays, except Federal holidays.

FOR FURTHER INFORMATION CONTACT: Jan Thor, Standards Staff, at the address above, telephone (425) 227–2127.

SUPPLEMENTARY INFORMATION:

Comments Invited

Interested persons are invited to comment on the proposed AC by submitting such written data, views, or arguments as they may desire. Commenters should identify AC 25.491–1 and submit comments, in duplicate, to the address specified above. All communications received on or before the closing date for comments will be considered by the Transport Standards Staff before issuing the final AC. The proposed AC can be found and downloaded from the Internet at *http://www.faa.gov/avr/air/airhome.htm*, at the link titled "Draft AC's." A paper copy of the proposed AC may be obtained by contacting the person named above under the caption **FOR FURTHER INFORMATION**.

Discussion

This proposed AC sets forth acceptable methods of compliance with the provisions of 14 CFR § 25.491 dealing with the certification requirements for taxi, takeoff and landing roll design loads. Guidance information is provided for showing compliance with that regulation relating to structural design for airplane operation on paved runways and taxiways normally used in commercial operation. Other methods of compliance with the requirements may be acceptable.

Issued in Renton, Washington, on October 7, 1999.

Donald L. Riggin,

Acting Manager, Transport Airplane Directorate, Aircraft Certification Service, ANM–100.

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